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REMOTELY CONTROLLED ORDNANCE CLEARING OPERATION ORDNANCE REMEDIATION REPORT

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14. ABSTRACT

The US Army Corps of Engineers (USACE) tasked AFRL to perform a subsurface ordnance removal operation using robotically controlled equipment within a nine-grid area (4.13 acres) of Ordnance Operable Unit 6, a 28 acre site located within the former Camp Croft, near Spartanburg, SC. This area was previously identified as an impact area that contained multiple metal fragments, mortar projectiles, smoke canisters, and fuzes within 8 to 12 inches of the ground surface. A two phase tasking plan was developed by USACE to clear the site of unexploded ordnance (UXO) items. The first phase tasking was assigned to AFRL to remove and sift the top 12" of soil by remote controlled excavation. The second phase task was to "mag and flag" the excavated area and then to continue the excavation process until all the UXO was cleared from the area. The job of removing and handling the UXO was performed by an Explosive Ordnance Disposal (EOD) certified contractor in support of the USACE.

15. SUBJECT TERMS

Camp Croft, Croft Field, USACE, UXO, EOD, robotics, excavation, remediation, ARTS, Spartanburg, AOE, OOU6, Ordnance Operable Unit 6

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PREFACE

This report was originally released to the public in 2001. Minor administrative corrections have been made and photographs in the figures replaced with better quality images.

1.0 SCOPE

The U.S. Army Corps of Engineers (COE) tasked the Air Force Research Laboratory (AFRL), Robotics Research Team, to perform a subsurface ordnance removal operation using robotically controlled equipment within a nine-grid area (4.13 acres) of Ordnance Operable Unit 6 (00U6), a 28-acre site located within the former Camp Croft near Spartanburg, South Carolina. This nine-grid area was previously identified as an impact area that contained multiple metal fragments from 60mm and 81mm mortar projectiles, 105mm smoke canisters, and M-48 fuzes within 8 to 12 inches of the ground surface. A two-phase tasking plan was developed by the COE to clear the 4.13-acre site. The second phase task was to "mag and flag" the excavated area and then to continue the excavation process until all of the unexploded ordnance (UXO) was clear of the area. The job of removing and handling the UXO was performed by an Explosives Ordnance Disposal (EOD) certified contractor in support of the COE.

2.0 BACKGROUND

The AFRL Robotics Research Team was contacted by the COE to determine if AFRL had developed robotic technology for large construction vehicles that could be used to clear large areas of UXO in order to render previously owned government land safe for privatization. A capabilities demonstration of robotically controlled equipment was provided by AFRL. The COE's main interest was the ability to operate the large construction vehicles from a safe distance (outside the boundaries of the UXO site – a personnel safety issue) and the ability to clear or move large quantities of dirt in a short period of time; a cost effectiveness issue. A request for proposal followed soon thereafter that resulted in AFRL's tasking to use multiple robotically controlled equipment items to clear 12 inches of topsoil from the 4.13-acre site. Work began 19 March 2001 and was completed on 30 June 2001.

3.0 EQUIPMENT DESCRIPTIONS

The equipment used by AFRL during the ordnance removal operation included a remotely operated D8 bulldozer with blade, a remotely operated Caterpillar 325L "long reach" excavator, a remotely operated all-purpose remote transport system (ARTS) with front loader, a commercially leased sifter/shaker (Nordberg 90D), replaced later (30 May 2001) with the Nordberg ST170 (tracked vehicle), and a Mobile Command Center (MCC) in an enclosed panel truck that was used to transport and house the remote control stations for each of the remotely controlled vehicles. Each equipment item is described in more detail below.

3.1 Remote Controlled D8 Bulldozer with Blade

The bulldozer used for this remediation task was the Caterpillar D8N with blade. The dozer had previously participated in a Marine Corps sponsored mine countermeasure test that required a teleoperable vehicle control system (VCS) and armor plating. The armor plating added 10,000 lbs to the vehicle's base weight of 68,000 lbs. A system operator controlled the dozer through an Operator Control Unit (OCU). Cameras located on top of the cab of the dozer provided the operator with a view of dozer operations on the OCU monitor. The VCS was designed to be remotely operated from a line-of-sight distance of 1.5 miles. The remote site from which the

operator controlled the dozer at Camp Croft was 270 feet. The armor plated D8N dozer is pictured in Figure 1.

The task issued to AFRL by the COE was to remove one foot of topsoil over the entire 4.13 acre site and to remove UXO debris from that soil. The operational plan was to use the teleoperated dozer to "scrape" one foot of soil from the ground surface, to use the dozer to push the soil to the vicinity of the excavator, then to use the teleoperated excavator to "scoop up" the soil and place the contaminated soil onto the sifter/shaker to separate the UXO and other debris from the soil. This clearing scenario was accomplished by system operators controlling the dozer and excavator from a remote site 270 feet outside the boundary of the remediation site.

Figure 1: Armor Plated D8N Bulldozer with Blade

3.2 Remote Controlled 325L Excavator

The excavator used for this remediation task was the Caterpillar 325L (long reach) that had a 60-foot reach capability. The "long reach" capability makes the bucker-to-machine distance the maximum possible to offer some protection of the main platform in the event of a detonation during the remediation process. The excavator weighs approximately 65,000 lbs and is considered a large-scale remediation platform. A system operator controlled the excavator through an OCU located within the MCC. The MCC was located 270 feet outside site boundaries. The 325L excavator is pictured in Figure 2.

Figure 2: Remote Controlled Caterpillar 325L Excavator

3.3 Remote Controlled All-purpose Transport System (ARTS)

The remote controlled ARTS vehicle with front-end loader was used to move sifted soil from under the Nordberg 90 sifter/shaker to a "clean" area. A system operator controlled the ARTS vehicle through an OCU located within the MCC. The remote controlled ARTS vehicle is pictured in Figure 3.

Figure 3: Remote Controlled ARTS Vehicle

3.4 Nordberg 90D Sifter/Shaker

The Nordberg 90D Sifter/Shaker was a commercially leased item of equipment that was used to "sift" the soil that was placed on it by the excavator. The shaker grille was designed to remove debris greater than 2.5 inches in diameter. The sifter/shaker was powered by a diesel engine that had to be manually started and stopped for each sifting operation. The sifted soil would fall directly under the sifter and the debris would fall to the side. The Nordberg 90D was a fixed platform. Once placed in position, all soil had to be moved to it to be sifted. This item of equipment was replaced with the Nordberg ST170 Sifter/Shaker on 30 May 2001. A picture of the Nordberg 90D Sifter/Shaker could not be located.

3.5 Nordberg ST170 Sifter/Shaker

The Nordberg ST170 Sifter/Shaker was a commercially leased item of equipment that was also used to "sift" the soil that was placed on it by the excavator. The ST170 was a diesel-powered, self-propelled, tracked vehicle that could be moved under its own power on the remediation site. The shaker grille was designed to remove debris greater than 2.5 inches in diameter. The sifter/shaker was equipped with a handheld, eleven-function radio remote transmitter that enabled the operator to remotely start and stop the sifter/shaker. The sifted soil would fall onto a four-foot wide conveyer belt and then be discharged into a dump truck for transfer to a known safe area. The debris was discharged to the side of the sifter/shaker. Figure 4 pictures the Nordberg ST170 Sifter/Shaker.

Figure 4: Self-Propelled Nordberg ST170 Sifter/Shaker On-Site

3.6 Mobile Command Center for Remote Control Units

The Mobile Command Center (MCC) is a panel truck used by AFRL to house the OCU of the teleoperated equipment. Power to operate the OCU is provided by a portable generator. The panel truck is air conditioned and provides a clean, sheltered environment for both the equipment and operators. The MCC pictured in Figure 5 was located 270 feet outside the site boundary.

4.0 REMEDIATION OBJECTIVES

The objectives of the using remotely controlled large-scale construction vehicles were 1) to clear a large area of UXO in a minimum amount of time (and money) and 2) to minimize the exposure of personnel to the hazards of UXO remediation. It should be noted that during the actual remediation process, no operator or EOD personnel were closer than 270 feet to the boundaries of the remediation site.

Figure 5: Mobile Command Center for Teleoperated Equipment

5.0 CONDUCT OF CLEARING OPERATION

The strategy developed for the conduct of the clearing operation was determined to a large degree by the topography of the remediation site. The site was severely sloped from west to east with the eastern side being on the low side. The sifter/shaker and excavator were positioned on the lower eastern boundary which was relatively level. Figure 6 shows the equipment in position at the bottom of the hill.

Figure 6: Excavator and Sifter/Shaker Site Location

The strategy for clearing was to use the dozer to clear 12 inches of topsoil from the upper plateau and the sloped regions and push the contaminated soil down the hill to an area near the excavator where it could be picked up and placed on the sifter/shaker. After the soil was sifted, the teleoperated ARTS vehicle with a front-end loader was used to move the "clean" soil to a temporary staging area outside the boundaries of the remediation site. The clean soil would eventually be transported to the top of the hill and redistributed over the site from which it came.

5.1 Work Schedule Summary

On 19 March 2001, AFRL operator personnel arrived at Camp Croft and commenced clearing operations. Table 1 provides a summary of work performed during the period of performance that lasted through 24 June 2001. Information is from an AFRL operator journal.

Table 1: Remediation Work Schedule Summary

Day	March 2001	April 2001	May 2001	June 2001
1		Sun-At AFRL	Tue-D8/AOD 35s	Fri-Reposition
2		Mon-At AFRL	Wed-D8/AOE 163s	Sat-D8 Ops
3		Tue-At AFRL	Thu-AOE/Ops 330s	Sun-OFF
4		Wed-At AFRL	Fri-Standby	Mon-Hot Spots
5		Thu-At AFRL	Sat-AOE Debris 94s	Tue-Hot Spots
6		Fri-At AFRL	Sun-OFF	Wed-Reposition
7		Sat-At AFRL	Mon-AOE/ART 371s	Thu-Site Dress
8		Sun-At AFRL	Tue-D8/AOD 429s	Fri-Reposit AOE
9		Mon-At AFRL	Wed-Trvl AFRL	Sat-Too Wet
10		Tue-At AFRL	Thu-At AFRL	Sun-OFF
11		Wed-At AFRL	Fri-At AFRL	Mon-AOE Ops
12		Thu-At AFRL	Sat-At AFRL	Tue-AOE Ops
13		Fri-At AFRL	Sun-At AFRL	Wed-AOE Ops
14		Sat-At AFRL	Mon-At AFRL	Thu-AOE Ops
15		Sun-Return to Site	Tue-At AFRL	Fri-AOE Ops
16		Mon-Buy Tools/Gen	Wed-At AFRL	Sat-AOE Ops
17		Tue-D8/AOE Ops 75s	Thu-At AFRL	Sun-OFF
18		Wed-D8/AOE Ops 145s	Fri-At AFRL	Mon-AOE Ops
19	Mon-Pers. Arrive	Thu-Equip Maint	Sat-At AFRL	Tue-AOE Ops
20	Tue-Tree Removal	Fri-AOE Ops 224s	Sun-At AFRL	Wed-AOE Ops
21	Wed-Tree Removal	Sat-AOE Ops 178s	Mon-At AFRL	Thu-AOE Ops
22	Thu-D8 Ops Start	Sun-AOE/ARTS 176s	Tue-At AFRL	Fri-AOE Ops
23	Fri-D8 Ops	Mon-AOE/ARTS 178s	Wed-At AFRL	Sat-AOE End Op
24	Sat-D8/AOE Trees	Tue-AOE/ARTS 180s	Thu-At AFRL	Sun-Trvl AFRL
25	Sun-OFF	Wed-Rain	Fri-At AFRL	
26	Mon-D8/AOE Ops	Thu-Reposition Equip	Sat-At AFRL	
27	Tue-D8 Ops	Fri-AOE/ARTS 141s	Sun-At AFRL	
28	Wed-D8 Ops	Sat-AOE/ARTS 150s	Mon-At AFRL	
29	Thu-Rain Day	Sun-OFF	Tue-Trvl to Site	
30	Fri-Rain Day	Mon-AOE Ops 161s	Wed-Restart 328s	
31	Sat-Return AFRL		Thu-Reposit Equip	

5.2 Work Journal Data Summary

The following work data information was extracted from Table 1.

1) Number of days start to finish of remediation work 98 days

2) Number of days back at AFRL, Tyndall 34 days
   - 35% of total time at AFRL

3) Number of days dedicated to task	64 days
4) Number of days used for travel	5 days
5) Number of rain days	3 days
6) Number of onsite Sundays – no work	7 days
7) Number of onsite work days (#3 minus 4, 5 & 6) - 50% of total time working onsite	49 days
8) Number of days excavating/sifting work performed - 59% of available workdays used excavator	29 days
9) Number of days when # of scoops sifted were recorded	18 days
10) Average # scoops per day over 18-day period	216 scoops
11) Most scoops per day achieved – 1 May	435 scoops
12) Least scoops per day recorded – 17 April	75 scoops
13) Average # scoops per day over 11 days during April	158 scoops
14) Average # scoops per day over 7 days during May	307 scoops

5.3 Remediation Rate Determination

The remediation rate or the number of scoops of soil that could be sifted during a normal workday was determined or impacted by the following factors:

1) Telemetry links to vehicles had to be line-of-sight to operate

2) Video links had to be operable

3) All personnel had to be 270 feet outside the boundaries of the remediation site before the equipment could be operated (safety requirements).

4) Tele-remote operations ceased each time a target UXO item was identified to allow EOD personnel to remove the item from the site.

5) Tele-remote operations ceased each time EOD personnel were onsite to conduct "mag and flag" operations or to move and replace the dump truck.

6) The remediation process was suspended during vehicle maintenance (repair/replace starters, hydraulic lines, cabling, antennas, etc.)

7) Range safety personnel (other contractor personnel) had to be onsite before AFRL personnel could operate equipment teleremotely.

8) Extended day work hour (overtime) allocations between AFRL equipment operators and other contractor support personnel were not the same. This fact placed a constraint on AFRL operator's ability to complete work (EOD Safety Representative had to be onsite).

The collective impact of these "production factors" was to reduce the amount of time AFRL operators had to complete the remediation process. From the operator's journal, it was evident that on many occasions AFRL operations were suspended due to the non-availability of range safety personnel necessary to keep the range open for extended periods.

5.4 Remediation Results

The remediation process of bulldozing 12 inches of topsoil from each grid, pushing the contaminated soil to the vicinity of the excavator, and then using the excavator to scoop the soil unto the sifter/shaker resulted in the recovery of approximately 150 rounds of unexploded ordnance (UXO) and other UXO debris. Figure 7 is a photograph of three 105mm rounds and associated fuse parts that were recovered from the soil buildup next to the sifter/shaker. These UXO items were removed from the site by EOD-certified personnel and placed in a metal storage container off-site. Figure 8 is a photograph of additional UXO items recovered from the remediation site. The exact number and type of UXO items recovered from each grid could not be determined by AFRL personnel because AFRL was not tasked to handle, store or dispose of UXO debris.

The criteria for determining whether a grid was "clean" was made by EOD personnel who conducted "mag and flag" operations by using an EM 61 handheld metal detector to sweep the grid after the topsoil had been removed. Hot spots detected by the EM 61 metal detector were flagged and the area was bulldozed a second time. This process was repeated until all hot spots were eliminated. After the hot spots were eliminated, EOD personnel would certify the area clean. This process was repeated in each of the nine grids specified.

Figure 7: Recovered 105mm UXO

Figure 8: Recovered UXO

5.5 Remediation Rate Estimates

From the teleremote remediation experience gained at Camp Croft, remediation rates can be calculated for future operations. Table 2 depicts the estimated number of days it would take to clear an area to a depth of one foot when using the following assumptions.

a. Bucket capacity is .5 cubic yard per scoop

b. Remediation rate is 75 scoops per hour

c. Excavator operates 4 hours per day = 300 scoops per day

Table 2: Remediation Rate Table Estimate

Site Size	Depth	Cubic Yards	Scoops/Day	Days Required
1 Acre	1 Ft	1613.3	300	10.75
2 Acres	1 Ft	3226.6	300	21.51
3 Acres	1 Ft	4839.9	300	32.26
4 Acres	1 Ft	6453.2	300	43.03
5 Acres	1 Ft	8066.5	300	53.77

Remediation rate table estimates for depths varying from one to four feet and bucket capacities varying from .5 cubic yards to 2.0 cubic yards are contained in Appendix A.

5.6 New Technologies

The steep side-slope of the remediation site coupled with the requirement to teleoperate the equipment from a 270-foot standoff distance presented a challenging work environment for AFLR operators. To operate e equipment safely and to ensure all terrain within the nine-area grid was remediated, new technologies were incorporated. A GPS mapping system was used to track areas covered. A visual display of the dozer's location could be viewed on the OCU monitor. This capability allowed the dozer operator to completely clear the designated area without actually seeing the vehicle during the clearing operation. An inclinometer was also installed on the D8 dozer that provided side-slope information to the vehicle operator on the OCU monitor. This information was used to keep the vehicle from rolling over while operating on the side-slope.

5.7 Lessons Learned

The remediation effort at Camp Croft was a two part, two contractor effort. The first part, performed by AFRL, was to use teleoperated equipment to remove 12 inches of UXO contaminated topsoil and to sift the soil to separate contaminates from the soil. The second part, performed by the other COE contractor, was to locate, identify, handle, store, and dispose of all UXO recovered. By participating in this "joint" effort, AFRL benefited from the following lessons learned.

1) Multiple robotically controlled platforms could be controlled simultaneously without frequency interference with one another.

2) The use of robotically controlled large construction vehicles dramatically increased the amount of soil that could be moved and sifted per unit of time. The original estimate of 90 weeks to complete the remediation process manually was reduced to nine weeks. This ten to one reduction in time (and money) provided the COE with an opportunity to achieve significant cost benefits.

3) The use of a dozer was required at Camp Croft due to the severe slope and the large number of trees/tree stumps that had to be removed. Under a more level field condition, the need for dozer operations may not be required. Eliminating the dozer would 1) reduce the amount of time required to complete the work, 2) eliminate double handling the soil, 3) reduce the likelihood of encountering "live" ordnance with equipment, 4) eliminate dozer maintenance time and costs, and 5) reduce dozer transportation costs.

4) The use of the ARTS vehicle was originally required because the first sifter/shaker (Nordberg 90D) used was not self-propelled, did not have a conveyor belt discharge, and had to have the clean soil removed periodically from directly beneath it. When the sifter/shaker was upgraded on 30 May to the self-propelled Nordberg ST170 with a conveyor belt discharge, the AFRTS vehicle was no longer required. By eliminating the requirement to operate the ARTS vehicle, the time required to complete the remediation effort by AFRL was further reduce.

5) A standardized daily work sheet was not available for use by AFRL operators during this remediation effort. A daily journal was maintained by one of the operators that provided valuable information on work accomplished. However, without a standardized format, some data was not recorded. A daily remediation worksheet was developed and is enclosed in Appendix B.

6) Approximately 40% of on-site work time was devoted to maintenance of the three vehicles AFRL used and their teleremote systems. The amount of time spent on maintenance *could* be reduced through the following actions.
    a. Prepare spare parts list for most frequently used items for each vehicle system
    b. Take spare parts for each vehicle to working site
    c. Consider taking dedicated mechanic to site. This person could provide a multitude of services.
    d. Consider taking robotic technician to site

Any reduction in maintenance down-time would increase the availability of vehicles to perform their primary remediation tasks. Increased equipment availability should reduce the total time to complete the overall task.

6.0 CONCLUSIONS

The use of robotically controlled construction vehicles to remove subsurface UXO from a known impact area demonstrated the capability of the equipment to move large amounts of soil quickly without endangering lives. The cost benefits derived by using teleoperated equipment is significant. The savings in time to clear UXO from a designated site is estimated to be ten times faster than manual clearance.

Multiple vehicles can be operated simultaneously further leveraging the capabilities of the large construction vehicles to clear UXO debris from the soil. Using only one teleremote operator for each vehicle reduces manpower requirements for a remediation mission.

Portions of the remediation process performed at Camp Croft were video recorded to provide a visual record. A synopsis of that video is provided in Appendix C.

APPENDIX A

REMEDIATION TABLES

Table A-1. Remote Clearing Rate (0.5 Cubic Yard Bucket Capacity)

Site Size	Depth	Cubic Yards	Scoops/Day	Op Days Required
1 Acre	1 Ft	1613.3	300	10.75
	2 Ft	3226.6	300	21.51
	3 Ft	4839.9	300	32.26
	4 Ft	6453.2	300	43.03
2 Acre	1 Ft	3226.6	300	21.51
	2 Ft	6433.2	300	43.03
	3 Ft	9649.8	300	64.33
	4 Ft	12866.4	300	85.78
3 Acre	1 Ft	4839.3	300	32.26
	2 Ft	9678.6	300	64.52
	3 Ft	14517.9	300	96.78
	4 Ft	19357.2	300	129.05
4 Acre	1 Ft	6453.2	300	43.03
	2 Ft	12906.4	300	86.04
	3 Ft	19359.6	300	129.05
	4 Ft	25812.8	300	172.08
5 Acre	1 Ft	8066.5	300	53.77
	2 Ft	16133.0	300	107.55
	3 Ft	24199.5	300	161.33
	4 Ft	32266.0	300	215.11

Table A-2. Remote Clearing Rate (1.0 Cubic Yard Bucket Capacity)

Site Size	Depth	Cubic Yards	Scoops/Day	Op Days Required
1 Acre	1 Ft	1613.3	300	5.38
	2 Ft	3226.6	300	10.75
	3 Ft	4839.9	300	16.13
	4 Ft	6453.2	300	21.51
2 Acre	1 Ft	3226.6	300	10.75
	2 Ft	6433.2	300	21.44
	3 Ft	9649.8	300	32.16
	4 Ft	12866.4	300	42.89
3 Acre	1 Ft	4839.3	300	16.13
	2 Ft	9678.6	300	32.26
	3 Ft	14517.9	300	48.39
	4 Ft	19357.2	300	64.52
4 Acre	1 Ft	6453.2	300	21.51
	2 Ft	12906.4	300	43.02
	3 Ft	19359.6	300	64.53
	4 Ft	25812.8	300	86.04
5 Acre	1 Ft	8066.5	300	26.88
	2 Ft	16133.0	300	53.78
	3 Ft	24199.5	300	80.66
	4 Ft	32266.0	300	107.55

Table A-3. Remote Clearing Rate (1.5 Cubic Yard Bucket Capacity)

Site Size	Depth	Cubic Yards	Scoops/Day	Op Days Required
1 Acre	1 Ft	1613.3	300	3.58
	2 Ft	3226.6	300	7.17
	3 Ft	4839.9	300	10.75
	4 Ft	6453.2	300	14.34
2 Acre	1 Ft	3226.6	300	7.17
	2 Ft	6433.2	300	14.29
	3 Ft	9649.8	300	21.44
	4 Ft	12866.4	300	28.59
3 Acre	1 Ft	4839.3	300	10.75
	2 Ft	9678.6	300	21.5
	3 Ft	14517.9	300	32.26
	4 Ft	19357.2	300	43.01
4 Acre	1 Ft	6453.2	300	14.34
	2 Ft	12906.4	300	28.68
	3 Ft	19359.6	300	43.02
	4 Ft	25812.8	300	57.36
5 Acre	1 Ft	8066.5	300	17.92
	2 Ft	16133.0	300	35.85
	3 Ft	24199.5	300	53.77
	4 Ft	32266.0	300	71.70

Table A-4. Remote Clearing Rate (2.0 Cubic Yard Bucket Capacity)

Site Size	Depth	Cubic Yards	Scoops/Day	Op Days Required
1 Acre	1 Ft	1613.3	300	2.68
	2 Ft	3226.6	300	5.38
	3 Ft	4839.9	300	8.06
	4 Ft	6453.2	300	10.75
2 Acre	1 Ft	3226.6	300	5.38
	2 Ft	6433.2	300	10.72
	3 Ft	9649.8	300	16.08
	4 Ft	12866.4	300	21.44
3 Acre	1 Ft	4839.3	300	8.06
	2 Ft	9678.6	300	16.13
	3 Ft	14517.9	300	24.20
	4 Ft	19357.2	300	32.26
4 Acre	1 Ft	6453.2	300	10.75
	2 Ft	12906.4	300	21.51
	3 Ft	19359.6	300	32.26
	4 Ft	25812.8	300	43.02
5 Acre	1 Ft	8066.5	300	13.44
	2 Ft	16133.0	300	26.88
	3 Ft	24199.5	300	40.33
	4 Ft	32266.0	300	53.77

APPENDIX B

REMOTE CONTROLLED REMEDIATION
DAILY WORK SHEET

(To be filled out by each vehicle operator)

DATE: _____

OPERATOR NAME: _____

TYPE EQUIPMENT: D8 DOZER AOE/325L ARTS OTHER (Circle one)

WEATHER CONDITIONS: _____

START OPERATION TIME: _____

STOP OPERATION TIME: _____

TOTAL TIME VEHICLE OPERATED: _____

TYPE WORK PERFORMED: _____

MAINTENANCE REQUIRED: YES NO

DESCRIBE MAINTENANCE PERFORMED: _____
_____
_____

TIME REQUIRED TO PERFORM MAINTENANCE: _____

FOR AOE – NUMBER OF SCOOPS PERFORMED: _____

PROBLEMS ENCOUNTERED: _____
_____
_____
_____
_____

OPERATOR COMMENTS: _____
_____
_____
_____

LIST OF SYMBOLS, ACRONYMS, AND ABBREVIATIONS

ARTS	remote controlled all-purpose transport system
AFRL	Air Force Research Laboratory, Robotics Research Team
COE	U.S. Army Corps of Engineers
EOD	explosives ordnance disposal
MCC	mobile command center
OCU	operator control unit
UXO	unexploded ordnance
VCS	vehicle control system